TECHNOSPHERE SAFETY
ТЕХНОСФЕРНАЯ БЕЗОПАСНОСТЬ

UDC 614.84 *Original article*
https://doi.org/10.23947/2541-9129-2023-7-4-30-39

Analysis of Water Consumption During Fire Extinguishing at Objects of Different Functional Fire Hazard Classes

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Abstract
Introduction. Fire-fighting water supply systems play a primary role in ensuring effective fire extinguishing. Many researchers both in our country and abroad have considered the requirements for fire-fighting water supply and problematic issues in this area. At the same time, in order to update the requirements for fire-fighting water supply, it is necessary to study the actual water consumption on fires, taking into account the characteristics of fire objects. The aim of this research was to analyze the water consumption for outdoor firefighting depending on the characteristics of the fire object and compare the actual water consumption with the requirements of regulatory documents on fire safety.
Methods and Materials. The authors used statistical data on fires in the Russian Federation for 2019–2021 from the federal state information system "Federal Database "Fires". Methods of statistical data analysis and classification of statistical data were used to determine the actual water consumption for outdoor firefighting, depending on the class of functional fire hazard of the fire object. Visualization of the obtained results was performed by the method of graphical representation of data in the form of histograms and pie charts.
Results. The analysis showed that the highest average water consumption was required for objects of the functional fire hazard class F1.2 "hotels, dormitories (with the exception of apartment-type dormitories), dormitory buildings of sanatoriums and rest homes of general type, campsites" — 10.7 l/s. For apartment buildings, the highest average water consumption was required to extinguish fires that had arisen in the attic — 10 l/s and in the garret — 9.2 l/s.
Discussion and Conclusion. The results of the analysis can be used to clarify the requirements for water consumption for outdoor firefighting, depending on the functional fire hazard class of the object and the number of floors of buildings. In order to meet these requirements, regular monitoring of fire-fighting water supply systems is required, as well as timely maintenance and repair of external and internal fire-fighting water supply systems.

Keywords: water consumption, fire, functional fire hazard, building, number of floors

Acknowledgements. The authors would like to thank the editorial board and the reviewers for their attentive attitude to the article and for the specified comments that improved the quality of the article.

For citation. Kondashov AA. Bobrinev EV, Udavtsova EYu, Ryumina SI. Analysis of Water Consumption during Fire Extinguishing at Objects of Different Functional Fire Hazard Classes. *Safety of Technogenic and Natural Systems.* 2023;7(4):30–39. https://doi.org/10.23947/2541-9129-2023-7-4-30-39

Научная статья

Анализ расхода воды при тушении пожаров на объектах разных классов функциональной пожарной опасности

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Аннотация
Введение. Системы противопожарного водоснабжения играют первостепенную роль в обеспечении эффективного тушения пожаров. Требования к противопожарному водоснабжению и проблемные вопросы в этой области рассматривались многими исследователями как в нашей стране, так и за рубежом. В то же время для актуализации требований к противопожарному водоснабжению необходимо изучение фактического расхода воды на пожарах с учетом особенностей объектов пожара. Целью настоящего исследования является анализ расхода воды на наружное пожаротушение в зависимости от характеристик объекта пожара и сравнение фактического расхода воды с требованиями нормативных документов по пожарной безопасности.
Методы и материалы. Использованы статистические данные о пожарах в Российской Федерации за 2019–2021 годы, содержащиеся в федеральной государственной информационной системе «Федеральный банк данных «Пожары». Для определения фактического расхода воды на наружное пожаротушение в зависимости от класса функциональной пожарной опасности объекта пожара использованы методы статистического анализа данных и классификации статистических данных. Визуализация полученных результатов выполнена методом графического представления данных в виде гистограмм и круговых диаграмм.
Результаты исследования. Проведенный анализ показал, что наибольший средний расход воды требуется для объектов класса функциональной пожарной опасности Ф1.2 «гостиницы, общежития (за исключением общежитий квартирного типа), спальные корпуса санаториев и домов отдыха общего типа, кемпингов» — 10,7 л/с. Для многоквартирных жилых домов наибольший средний расход воды требуется для тушения пожаров, возникших на чердаке — 10 л/с и в мансарде — 9,2 л/с.
Обсуждение и заключение. Результаты проведенного анализа могут быть использованы для уточнения требований к расходу воды на наружное пожаротушение в зависимости от класса функциональной пожарной опасности объекта и этажности зданий. Для выполнения данных требований необходим регулярный контроль систем противопожарного водоснабжения, а также своевременное обслуживание и ремонт наружных и внутренних водопроводов противопожарного водоснабжения.

Ключевые слова: расход воды, пожар, функциональная пожарная опасность, здание, этажность

Благодарности. Авторы выражают благодарность редакции и рецензентам за внимательное отношение к статье и указанные замечания, которые позволили повысить ее качество.

Для цитирования. Кондашов А.А., Бобринев Е.В., Удавцова Е.Ю., Рюмина С.И. Анализ расхода воды при тушении пожаров на объектах разных классов функциональной пожарной опасности. *Безопасность техногенных и природных систем.* 2023;7(4):30–39. https://doi.org/10.23947/2541-9129-2023-7-4-30-39

Introduction. The task of determining the required water consumption for outdoor firefighting is of paramount importance to ensure effective actions of operational fire protection units when extinguishing fires. Data on water consumption for outdoor firefighting are used in determining the composition of forces and means of operational fire protection units, drawing up fire extinguishing plans, determining the requirements for outdoor fire water supply systems.

The problems associated with the supply of water to outdoor fire-fighting water supply systems have been considered by many researchers [1–4]. In particular, Zayko V.A., Ilyin N.A., Sargsyan A.M. paid special attention to fire extinguishing organization in small settlements, where, as a rule, there were no fire-fighting water supply systems and the rapid arrival of special fire equipment was not always ensured [5]. Abrosimov Yu.G., Kiselev L.Yu. came to the conclusion that it was necessary to develop new standards and adjust the existing regulatory documents regarding the estimated extinguishing time and water costs for firefighting for cities with a population of more than a million people [6]. Chudakov A.A., Metelkin I.I., Shumilin V.V. analyzed the available information about hydraulic structures intended for fire-fighting purposes [7]. Kalach A.V., Rodin V.A., Sinegubov S.V. considered optimizing the number and distribution of hydrants for outdoor fire-fighting water supply and pumping stations using various metrics measuring distance [8]. Kelishek S., Drzhimala T. considered the main problems related to water supply of fire water supply systems in high residential buildings [9].

Other publications present the results of studies on the reliability of fire-fighting water supply to attract the attention of specialists to this issue [10–13].

Code of Rules SP 8.13130.2020 "The fire protection systems. Outdoor fire-fighting water supply. Fire safety requirements"[1] ((hereinafter — SP 8.13130.2020) defines the requirements for water consumption for outdoor firefighting.

For buildings of functional fire hazard classes (hereinafter referred to as FFH) F1, F2, F3, F4, water supply during fire extinguishing depends on the number of storeys and the building volume and varies from 10 to 35 liters/s per fire. For buildings and structures of F5 FFH class, water supply depends on the degree of fire resistance, on the class of structural fire hazard and on the category of buildings and structures for explosion and fire hazard, as well as on the building volume and ranges from 10 to 100 liters/s per fire.

However, at the same time, there is no specification of the requirements for water consumption for outdoor fire extinguishing for buildings and structures, depending on the FFH classes. The task of the authors was to determine the actual volume of water supply during fire extinguishing, taking into account functional fire hazard classes of fire objects.

Materials and Methods. To determine water consumption when extinguishing fires at various facilities, an analysis of fires that occurred in the Russian Federation in 2019-2021 in the following subjects was carried out: Moscow, Voronezh, Tula, Leningrad, Murmansk, Nizhny Novgorod, Samara, Sverdlovsk, Tyumen regions, Krasnodar, Krasnoyarsk, Primorsky, Stavropol Territories, the Republic of Dagestan, Buryatia, Yamalo-Nenets Autonomous Okrug.

Statistical data on fires and the actual consumption of water for their extinguishing for 2019-2021 were obtained from the fire data bank[2].

Results. Table 1 shows the distribution of fires by water consumption for objects of various FFH classes, defined in accordance with Article 32 of the Technical Regulations on Fire Safety Requirements[3]. Figure 1 provides the distribution of fires by water consumption for all objects. Fires with water consumption of no more than 7 liters/s accounted for 79% of the total number of fires, fires with water consumption of more than 60 liters/s were 0.62%, with water consumption of more than 100 liters/s — 0.18%.

Table 1

Distribution of fires by water consumption depending on functional fire hazard class of the fire object, % of the total number of fires

FFH class	Water consumption, liters/s												Average consumption
	0–3.5	4–7	7.5–12	12.5–20	21–30	31–40	41–60	61–80	81–100	101–120	121–140	> 140	
F1	**47.2**	**33.3**	**10.0**	**6.6**	**2.1**	**0.4**	**0.3**	**0.1**	**0.0**	**0.0**	**0.0**	**0.0**	**6.8**
F1.1	63.9	22.9	4.9	2.8	2.8	0.7	2.1	0.0	0.0	0.0	0.0	0.0	6.6
F1.2	42.3	27.4	11.3	6.9	5.6	1.6	2.8	0.4	1.2	0.4	0.0	0.0	10.7
F1.3	69.8	19.0	4.8	3.9	1.6	0.4	0.3	0.1	0.1	0.0	0.0	0.0	5.7
F1.4	36.2	40.3	12.5	7.9	2.3	0.4	0.2	0.0	0.0	0.0	0.0	0.0	7.3
F2	**43.1**	**28.5**	**12.4**	**7.3**	**7.3**	**0.7**	**0.7**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**8.2**
F2.1	42.0	27.5	14.5	7.2	7.2	0.0	1.4	0.0	0.0	0.0	0.0	0.0	8.4
F2.2	30.0	35.0	15.0	5.0	10.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	9.9
F2.3	47.8	21.7	8.7	17.4	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.8
F2.4	52.0	32.0	8.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7
F3	**51.6**	**30.4**	**7.5**	**6.3**	**2.8**	**0.6**	**0.5**	**0.2**	**0.1**	**0.1**	**0.0**	**0.0**	**7.0**
F3.1	55.0	25.5	7.5	6.7	2.8	0.9	0.9	0.4	0.1	0.1	0.0	0.0	7.4

[1] *The fire protection systems. Outdoor fire-fighting water supply. Fire safety requirements*. Свод правил СП 8.13130.2020. Electronic fund of legal and regulatory documents. URL: https://docs.cntd.ru/document/565391175 (accessed 14.08.2023)

[2] *O vnesenii izmenenii v Poryadok ucheta pozharov i ikh posledstvii, utverzhdennyi prikazom MChS Rossii ot 21 noyabrya 2008 g. No. 714.* Order of the Ministry of Emergency Situations of Russia of 17.11.2020 No. 848. Information and legal portal Garant.ru. URL: https://www.garant.ru/products/ipo/prime/doc/400020288/ (accessed 14.08.2023)

[3] *Tekhnicheskii reglament o trebovaniyakh pozharnoi bezopasnosti.* Federal Law No. 123-FZ of 22.07.2008. Electronic fund of legal and regulatory documents.URL: https://docs.cntd.ru/document/902111644 (accessed 14.08.2023)

FFH class	Water consumption, liters/s												Average consumption
	0–3.5	4–7	7.5–12	12.5–20	21–30	31–40	41–60	61–80	81–100	101–120	121–140	> 140	
F3.2	50.9	24.2	8.6	9.8	4.0	1.4	0.6	0.4	0.0	0.0	0.0	0.0	7.9
F3.3	62.5	0.0	0.0	37.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.2
F3.4	57.1	36.7	4.1	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	5.5
F3.5	60.7	23.4	7.0	4.9	2.0	0.8	0.8	0.4	0.0	0.0	0.0	0.0	6.6
F3.6	46.9	37.7	7.3	5.3	2.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	6.4
F3.7	43.8	27.1	12.5	10.4	6.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.8
F4	**53.7**	**23.9**	**8.2**	**8.5**	**3.4**	**0.3**	**0.8**	**0.2**	**0.5**	**0.5**	**0.2**	**0.3**	**8.3**
F4.1	55.8	25.7	6.2	8.8	1.8	0.0	0.9	0.0	0.0	0.0	0.0	0.9	8.0
F4.2	69.2	19.2	7.7	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.1
F4.3	52.4	23.7	8.7	8.7	4.0	0.4	0.8	0.2	0.6	0.0	0.2	0.2	8.5
F5	**49.7**	**29.4**	**8.7**	**7.1**	**2.9**	**0.8**	**0.7**	**0.3**	**0.1**	**0.2**	**0.0**	**0.0**	**7.6**
F5.1	40.9	27.9	11.5	10.1	5.5	1.4	1.5	0.7	0.2	0.2	0.1	0.0	9.7
F5.2	53.8	28.4	7.4	6.4	2.3	0.8	0.5	0.3	0.1	0.1	0.0	0.1	7.0
F5.3	46.5	35.8	9.7	5.4	1.6	0.3	0.5	0.1	0.0	0.1	0.1	0.0	6.7
Total	**47.9**	**32.5**	**9.6**	**6.7**	**2.3**	**0.5**	**0.4**	**0.2**	**0.0**	**0.0**	**0.0**	**0.0**	**7.0**

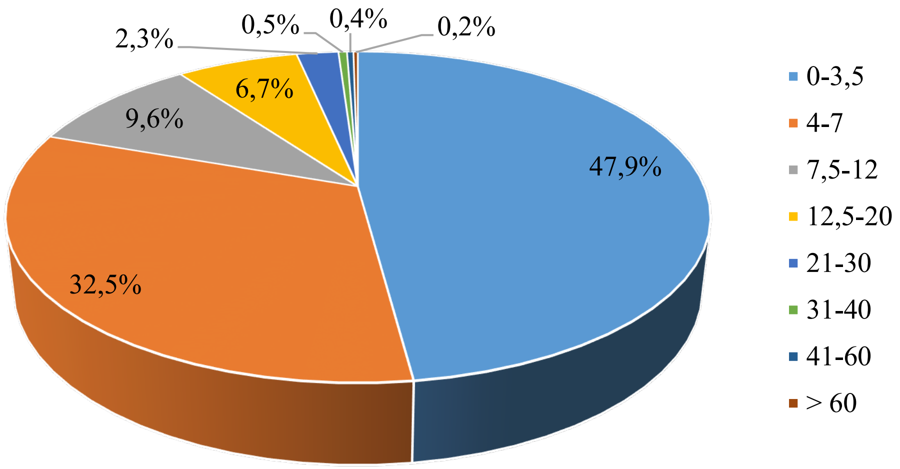

Fig. 1. Distribution of fires depending on water consumption

Figure 2 provides average water consumption during fire extinguishing, depending on the FFH class of fire object. The highest average water consumption was registered for objects of F1.2 FFH class "hotels, dormitories (except for apartment-type dormitories), bedroom buildings of sanatoriums and rest homes of general type, campsites" — 10.7 liters/s. In the second place by the value of the analyzed indicator were objects of F2.2 FFH class "museums, exhibitions, dance halls and other similar institutions in enclosed spaces" — 9.9 liters/s. In the third place — objects of F5.1 FFH class "industrial buildings, structures, production and laboratory facilities, workshops, crematoriums" — 9.7 liters/s.

The lowest average water consumption was registered for objects of F4.2 FFH class "buildings of educational institutions of higher education, organizations of additional professional education" — 5.1 liters/s, objects of F3.4 FFH class "buildings of medical organizations intended for medical activities, except for buildings belonging to F1.1 category" — 5.5 liters/s and objects of F1.3 FFH class "multi-apartment residential buildings, including apartment-type dormitories" — 5.7 liters/s.

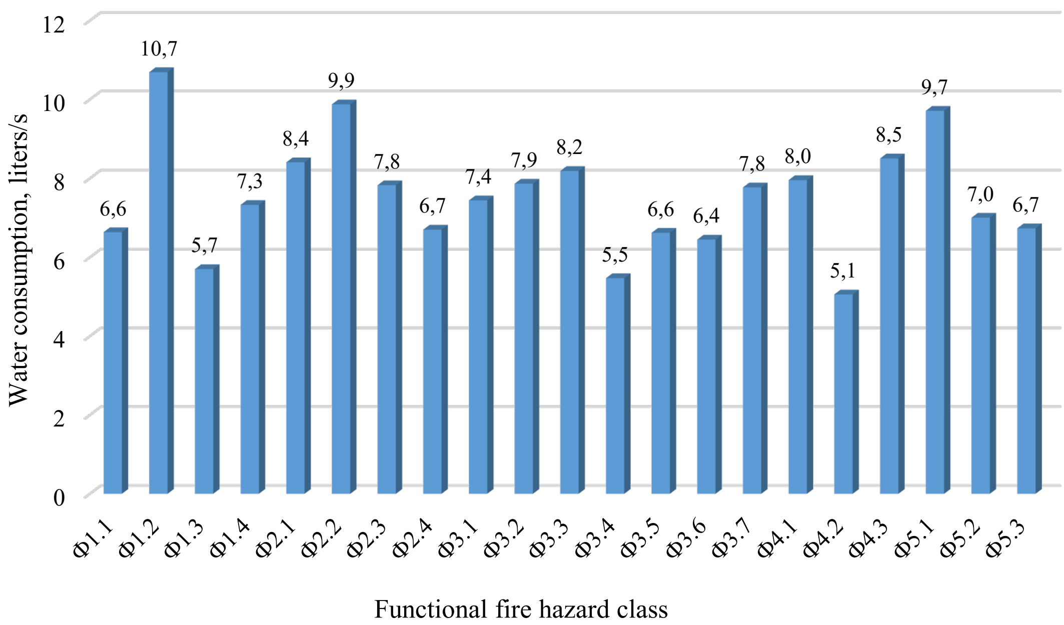

Fig. 2. Average water consumption depending on the functional fire hazard class of the fire object

For objects of F1 FFH class, fires with water consumption of no more than 7 liters/s accounted for 80.5% of the total number of fires; fires with water consumption of more than 60 liters/s were 0.15%, with water consumption of more than 100 liters/s — 0.08%.

For objects of F1.3 FFH class "multi-apartment residential buildings, including apartment-type dormitories", the distribution of fires by water consumption, depending on the floor on which the fire occurred, is shown in Table 2. Fires in apartments and on the premises of shared ownership (basements, mansards, attics) were considered. Figure 3 provides the distribution of fires by water consumption for these objects. Fires with water consumption of no more than 7 liters/s accounted for 88.4% of the total number of fires, fires with water consumption of more than 60 liters/s were 0.25%, with water consumption of more than 100 liters/s — 0.06%.

Table 2

Distribution of fires by water consumption, depending on the floor on which the fire occurred, for objects of F1.3 FFH class "multi-apartment residential buildings, including apartment-type dormitories", % of the total number of fires

Floor	Water consumption, l/s												Average consumption
	0–3.5	4–7	7.5–12	12.5–20	21–30	31–40	41–60	61–80	81–100	101–120	121–140	> 140	
basement	85.4	12.8	0.3	0.7	0.3	0.2	0.3	0.0	0.0	0.0	0.0	0.0	4.3
semibasement	70.3	25.0	0.0	1.6	1.6	1.6	0.0	0.0	0.0	0.0	0.0	0.0	5.3
1	64.5	19.7	6.8	5.6	2.1	0.5	0.4	0.2	0.0	0.0	0.0	0.0	6.2
2	67.4	21.2	4.2	3.5	2.1	0.4	0.6	0.2	0.1	0.1	0.0	0.0	6.1
3	76.6	19.4	1.5	1.9	0.4	0.1	0.0	0.1	0.1	0.0	0.0	0.0	4.6
4	78.9	18.0	1.8	0.8	0.2	0.4	0.0	0.1	0.0	0.0	0.0	0.0	4.5
5	81.5	14.9	1.7	1.3	0.3	0.2	0.1	0.1	0.0	0.0	0.0	0.0	4.4
6	77.0	19.7	0.8	2.2	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	4.5
7	77.9	20.0	1.2	0.3	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	4.4
8	83.7	13.4	1.5	0.0	0.6	0.3	0.3	0.0	0.0	0.0	0.0	0.3	4.8
9	77.4	18.9	2.3	1.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4
10	82.7	13.3	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	6.2
11	90.1	5.6	1.4	0.0	1.4	1.4	0.0	0.0	0.0	0.0	0.0	0.0	4.5
12	80.8	19.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.1
13	85.7	9.5	2.4	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2

Floor	Water consumption, l/s												Average consumption
	0–3.5	4–7	7.5–12	12.5–20	21–30	31–40	41–60	61–80	81–100	101–120	121–140	> 140	
basement	85.4	12.8	0.3	0.7	0.3	0.2	0.3	0.0	0.0	0.0	0.0	0.0	4.3
semibasement	70.3	25.0	0.0	1.6	1.6	1.6	0.0	0.0	0.0	0.0	0.0	0.0	5.3
14	75.0	22.2	0.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5
15	85.7	11.4	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0
16	83.8	10.8	2.7	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.3
17	89.5	10.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8
18–25	84.4	8.9	4.4	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.3
mansard	56.4	3.6	12.7	14.5	10.9	1.8	0.0	0.0	0.0	0.0	0.0	0.0	9.2
attic	44.3	20.3	14.9	9.8	5.7	2.2	1.6	0.6	0.3	0.3	0.0	0.0	10.0
Total	69.3	19.2	4.9	4.0	1.6	0.4	0.3	0.3	0.1	0.0	0.0	0.0	5.7

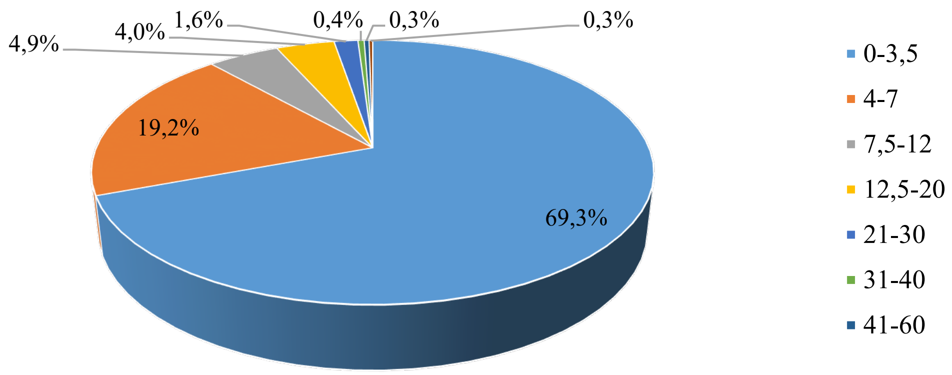

Fig. 3. Distribution of fires on objects of F1.3 FFH class depending on water consumption

Figure 4 provides average water consumption during fire extinguishing, depending on the floor on which the fire occurred, for objects of F1.3 FFH class. The highest average water consumption was registered for fires that occurred in the attic and mansard —10 and 9.2 liters/s respectively, as well as on the first and second floors — 6.2 and 6.1 liters/s. For fires that have arisen on other floors, the average consumption was in the range of 4–5 liters/s. The exception was the 10th floor. For fires on this floor, the average water consumption was 6.2 liters/s. Such a large expense was received due to one fire that occurred on September 30, 2021 in Tyumen at the address: Vostochny Administrative District, Narodnaya str., 10, for the extinguishing of which 15 units of fire equipment were involved and 26 fire-hose barrels were used. The total water consumption was 421 liters/s. With the exception of this fire, the average water consumption for fires on the 10th floor was 4.1 liters/s.

For objects of F2 FFH class, fires with water consumption of no more than 7 liters/s accounted for 71.5% of the total number of fires, fires with water consumption of more than 30 liters/s accounted for 1.46%, fires with water consumption of more than 60 liters/s were not registered during the period under review. The average water consumption at facilities of F2 FFH class was 8.2 liters/s.

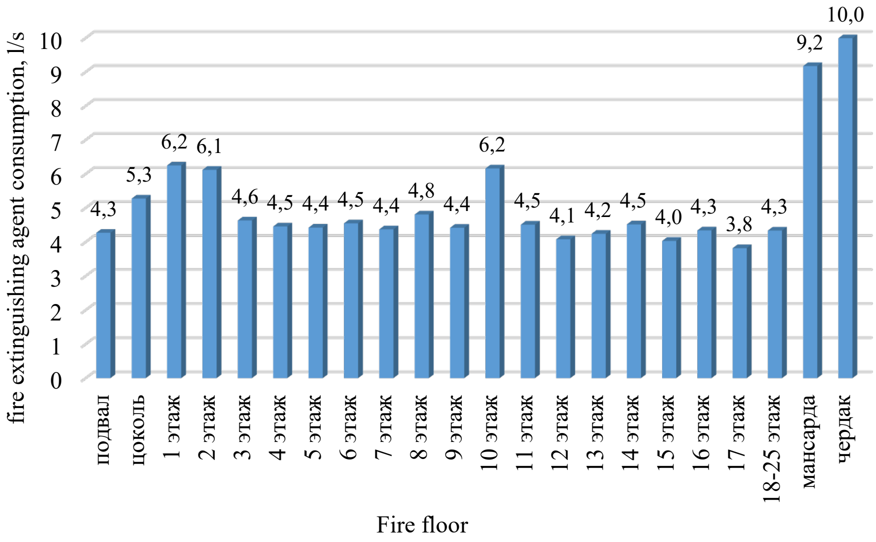

Fig. 4. Average water consumption depending on the floor of fire for objects of F1.3 FFH class

For objects of F3 FFH class, fires with water consumption of no more than 7 liters/s accounted for 81.9% of the total number of fires, fires with water consumption of more than 60 liters/s were 0.38%, with water consumption of more than 100 liters/s — 0.08%. The average water consumption at facilities of F3 FFH class was 7.0 liters/s.

For objects of F4 FFH class, fires with water consumption of no more than 7 liters/s accounted for 77.6% of the total number of fires, fires with water consumption of more than 60 liters/s accounted for 1.13%, with water consumption of more than 100 liters/s — 0.48%. The average water consumption at facilities of F4 FFH class is 8.3 l/s.

Figure 5 provides the distribution of fires by water consumption for objects of F5 FFH class. Fires with water consumption of no more than 7 liters/s accounted for 79.0% of the total number of fires, fires with water consumption of more than 60 liters/s were 0.35%, with water consumption of more than 100 liters/s — 0.18%. The average water consumption at facilities of F5 FFH class was 7.6 liters/s.

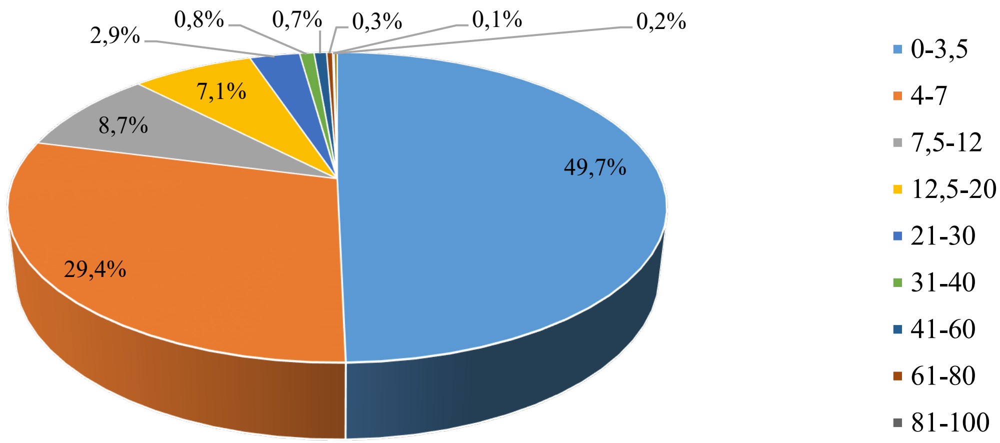

Fig. 5. Distribution of fires on objects of F5 FFH class depending on water consumption

Discussion and Conclusion. A comparison of the results obtained with the standards of SP 8.13130.2020 showed the following.

The actual water consumption per fire for buildings of F1.4 class "single-family residential buildings, including blocked ones" turned out to be higher than for buildings of F1.3 class "multi-apartment residential buildings, including apartment-type dormitories", that is, 7.3 liters/s versus 5.7 liters/s. The maximum water consumption per fire in settlements with low-rise buildings, according to SP 8.13130.2020, was 40 liters/s, while for 29 out of 1000 fires at facilities of F1.4 class, the actual water consumption exceeded 40 liters/s (Table 1).

According to Table 2, water consumption for external fire extinguishing per fire for buildings of F1.3 and F1.4 classes depended on the number of floors of buildings and their construction volume. As studies have shown, the actual water consumption practically did not depend on the floor on which the fire occurred, but increased significantly for fires in attics and mansards floors. At the same time, for buildings with a height of no more than two floors, the SP 8.13130.2020 determines water consumption of 10 liters/s per fire. The actual consumption for 109 out of 1000 fires for buildings of F1.4 class exceeded 12 liters/s.

The scientific novelty of this study consists in the analysis of actual water consumption for outdoor firefighting, depending on functional fire hazard class of the fire object. It is shown that the actual water supply during fire extinguishing differs significantly for different objects — from 5.1 liters/s per fire for objects of F 4.2 class to 10.7 liters/s for objects of F1.2 class.

Thus, the water supply system used for fire-fighting purposes must have a capacity that provides the total amount of water needed to extinguish a fire, that is, when planning fire-fighting water supply pipelines, it is necessary to take into account not only the requirements of SP 8.13130.2020, but also the features of protection facilities.

The results obtained in this work can be used to update the requirements of the code of rules SP 8.13130.2020, which will increase the effectiveness of actions of fire protection units in extinguishing fires.

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Received 13.09.2023
Revised 27.09.2023
Accepted 14.10.2023

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SI Ryumin: references, preparation of drawings, editing of the final version of the article.

Conflict of interest statement: the authors do not have any conflict of interest.

All authors have read and approved the final manuscript.

Поступила в редакцию 13.09.2023
Поступила после рецензирования 27.09.2023
Принята к публикации 14.10.2023

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Конфликт интересов: авторы заявляют об отсутствии конфликта интересов.

Все авторы прочитали и одобрили окончательный вариант рукописи.